Journal of Pediatric Psychology, 47(1), 2022, 1–11
doi: 10.1093/jpepsy/jsab082
Advance Access Publication Date: 15 September 2021
Original Research Article

Predicting Adolescent Electronic Cigarette Use: Differences by Never, Ever, and Current Users

Paul T. Enlow, [1,2] PhD, Desireé N. Williford,[3] MS, Katelyn F. Romm,[4] PhD, Geri A. Dino,[5] PhD, Melissa D. Blank,[3,5] PhD, Pamela J. Murray,[6] MD, MHP, Christine A. Banvard,[6] MD, and Christina L. Duncan,[3] PhD

[1]Center for Healthcare Delivery Science, Nemours Children's Health System, Wilmington, DE, USA, [2]Department of Pediatrics, Thomas Jefferson University Sidney Kimmel Medical College, Philadelphia, PA, USA, [3]Department of Psychology, West Virginia University, Morgantown, WV, USA, [4]Milken Institute of Public Health, George Washington University, Washington, DC, USA, [5]WV Prevention and Research Center, Department of Social and Behavioral Sciences, WVU School of Public Health, West Virginia University, Morgantown, WV, USA, and [6]Department of Pediatrics, Section of Adolescent Medicine, West Virginia University, Morgantown, WV, USA

All correspondence concerning this article should be addressed to Paul T. Enlow, PhD, Center for Healthcare Delivery Science, Nemours Children's Health System/A.I. duPont Hospital for Children, 1600 Rockland Road, Wilmington, DE 19806, USA. E-mail: paul.enlow@nemours.org

Received 21 December 2020; revisions received 19 July 2021; accepted 20 July 2021

Abstract

Objective Rising rates of adolescent electronic cigarette (ECIG) use is concerning because it can lead to adverse health outcomes and increased risk behavior. There are known predictors of ever versus never ECIG use, but less are known about risk factors for ever versus current use of ECIGs. Problem behavior theory (PBT) was used to evaluate possible risk factors for different ECIG use status. **Methods** Participants were 573 high school students who completed questionnaires measuring ECIG use, as well as constructs within the Social Environment, Perceived Environment, Personality, and Behavior domains of PBT. Multinomial logistic regression was used to evaluate how predictor variables differentiated between participants who reported (a) never use, (b) ever ECIG use, or (c) current ECIG use. **Results** Adolescents were more likely to endorse ever ECIG use than never use if they reported peer ECIG use, perceived more benefits and fewer costs (e.g., health) of ECIG use, higher extraversion, alcohol and cigarette use (never vs. ever vs. past 30 days), or attended a school with a higher percentage of socioeconomically disadvantaged students. Adolescents were more likely to report current ECIG use than ever ECIG use if they perceived fewer costs of ECIG use or used cannabis in their lifetime (yes/no). **Conclusions** PBT variables differentiated between ever ECIG use and never ECIG use. However, these variables did not differentiate between ever and current ECIG use. Identifying unique risk factors for current versus ever ECIG use is important to understanding persistent ECIG use and subsequent targeted prevention and intervention programs.

Key words: tobacco use; adolescents; risk behavior; health behavior.

Introduction

Use of electronic cigarettes (ECIGs) among adolescents rose dramatically over the past decade (Azagba et al., 2020). This increase has raised concerns among researchers and healthcare professionals about potential adverse consequences, including nicotine dependence (Lanza & Vasilenko, 2015), serious health problems from inhaling chemicals (Rubinstein et al., 2018), initiation of cigarette smoking (Vogel et al., 2019; Wills et al., 2021), and use of illicit substances (East et al., 2018). To

prevent and reduce ECIG use among adolescents, it is imperative that researchers identify risk factors for initiating and continuing to use ECIGs.

Adolescents who are susceptible to using ECIGs (i.e., not committed to abstaining from using ECIGs) have greater odds of initiating ECIG use, as well as using an ECIG within the past 30 days (Nicksic & Barnes, 2019). Furthermore, youth who were susceptible to ECIG use reported a number of risk factors, such as perceiving more benefits (e.g., enhancing popularity) from using an ECIG (Burnley et al., 2021; Margolis et al., 2021); being more likely to use alcohol, tobacco, or cannabis; experiencing psychological problems; or being exposed to tobacco at home (Margolis et al., 2021; Sawdey et al., 2019). Conversely, perceiving ECIGs as more harmful appears to protect against ECIG susceptibility (Burnley et al., 2021). These same factors (e.g., tobacco exposure, peer use) also appear to relate to actual ECIG use.

When compared with adolescents who never used an ECIG, those who *ever* (i.e., used an ECIG but not within the past 30 days) or *currently* use an ECIG (i.e., use of an ECIG within the past 30 days) had more risk factors (i.e., positive perceptions of ECIG, sensation seeking, male gender, parents and peers who used ECIGs) and fewer protective factors (i.e., perceiving ECIGs as having more health and social costs; Case et al., 2017; Mehra et al., 2019; Pokhrel et al., 2018; Vogel et al., 2018). Despite such advances in understanding the risk factors for adolescent ECIG use, there remain two important but understudied areas.

First, little is known about what variables differentiate between ever and current ECIG use. Understanding the risk factors for current versus ever ECIG use is important because more frequent ECIG use puts youth at greater risk of initiating cigarette use (Bold et al., 2018) and increases their exposure to nicotine and tobacco-related toxicants relative to non-ECIG users (Goniewicz et al., 2018). Differences in psychosocial and behavioral risk factors by frequency of ECIG use might be expected based on what has been reported for cigarettes. For example, peer smoking is associated with experimentation and more persistent smoking; whereas parent smoking is associated with persistent smoking but not experimentation (Chassin et al., 2000; Costello et al., 2008). Similarly, Burnley et al. (2021) demonstrated differences in perceptions of ECIG risks and benefits between adolescents who were not susceptible to ECIGs, susceptible to ECIGs, and had ever used an ECIG. Understanding how risk and protective factors vary by ECIG use status (i.e., never vs. ever vs. current) can lead to the development of more tailored, and thereby more effective (Skov-Ettrup et al., 2014) cessation and prevention strategies.

Second, previous work focused primarily on isolated sets of predictors of adolescent ECIG use. Although there are well-established associations among ECIG use and adolescent gender, ECIG expectancies, use of other substances, and parent and peer ECIG use, these predictors are typically investigated in separate studies (Kong et al., 2017; Mehra et al., 2019; Pokhrel et al., 2018). Fewer studies evaluated how a combination of individual and interpersonal factors influences ever and current ECIG use. Of the research that has examined a more comprehensive set of predictors of ECIG use patterns, findings indicated that receiving one's first ECIG from a family member, greater nicotine content, and having a higher percentage of friends who use ECIGs were associated with increased frequency of current ECIG use over and above the influence of maternal education (Vogel et al., 2018). Similar findings point to the contributions of alcohol and cigarette use in predicting adolescents' ECIG use over and above the influence of other known predictors (e.g., academic achievement, family structure, parental smoking; Kinnunen et al., 2018). Although a range of individual and interpersonal factors predict ever and current use of ECIG among adolescents, certain factors appear to be stronger contributors when multiple predictors are included in the same study. Thus, it remains unknown whether a variety of risk factors differentially predict current use of ECIGs compared with ever use among adolescents, as many studies combined these groups into single samples. To address this limitation, we grounded our study in a theoretical framework that allows for the incorporation of a multitude of risk and protective factors.

Problem Behavior Theory (PBT; Jessor, 1991) is a model of risk and protective factors related to deviant adolescent behavior that may provide broader-based or multi-factorial insight into the factors that differentiate between adolescents' ever and current use of ECIGs. PBT's five domains contain conceptually important variables related to substance use: (a) Biology/Genetic (e.g., family history of substance dependence), (b) Social Environment (e.g., demographics), (c) Perceived Environment (e.g., social norms and models), (d) Personality (e.g., psychological and individual factors), and (e) Behavior (e.g., substance use, academic performance). Among adolescents, PBT has been used to identify predictors of substance use (Donovan & Molina, 2014; Racz et al., 2011). A recent study suggested that PBT may also be better at explaining non-illicit drug use (Alexander et al., 2018). Adolescent ECIG use is associated with variables within the Social Environment (e.g., gender, socioeconomic status [SES]), Perceived Environment (e.g., parent and peer ECIG use), and Behavior (e.g., cigarette, alcohol, cannabis use) domains, as well as a narrow range of variables in the Personality domain (e.g., sensation seeking, ECIG expectancies). However, these variables are frequently examined in isolation.

This study aimed to identify PBT variables that differentiate among ECIG use status (never, ever, current use). Consistent with how e-cigarette (Walker et al., 2020) and cigarette use (Villanti et al., 2011) are defined in the broader literature, ECIG use status in this study was defined as: (a) never used an ECIG ("never users"), (b) used an ECIG at least once in their lifetime but not in the past 30 days ("ever users"), and (c) used an ECIG in the past 30 days ("current users"). The selected variables purposely represent four of the five PBT domains: Social Environment, Perceived Environment, Personality, and Behavior. The Biology domain was not included because risk and protective factor from this domain (e.g., family history of substance use, intelligence) could not be assessed in a valid manner in this study. Consistent with the extant literature, it was hypothesized that higher levels of risk factors (concurrent substance use, male gender, sensation seeking, extraversion, perceived benefits of ECIG use) and lower levels of protective factors (SES, perceived costs of ECIG use, conscientiousness) would increase the odds of being an *ever* user compared with *never* user. Similarly, it was hypothesized that higher levels of risk factors and lower levels of protective factors would increase the odds that an adolescent was a *current* versus *ever* user.

Materials and Methods

Participants

From 2015 to 2017 a sample of 573 adolescents (M_{age} = 15.98, SD = 1.21, 59% female) were recruited from four public high schools in West Virginia (N_{west} = 90; N_{east} = 240), Pennsylvania (N = 45), and Ohio (N = 141) and from one adolescent medicine clinic in West Virginia (N = 54). The average recruitment rate was 41.01% (range = 29.03–76.67%). The samples represented 23.02% (WV_{west}), 12.99% (WV_{east}), 9.03% (OH), and 5.42% (PA) of the total student body at each school, and 5.10% of the clinic population. Adolescents, aged 13–18 years, were eligible if they were enrolled in high school and spoke English. Adolescents who could not independently complete questionnaires per teacher or parent report were excluded.

Procedure

The West Virginia University Institutional Review Board, as well as school and clinic administrators, approved study procedures prior to data collection.

School Sites

Adolescents were recruited from health and psychology classes across the four high schools. A snowball recruitment method was used in which teachers were asked to recommend other teachers who might allow their class to participate in the study. Recruitment and data collection in schools occurred across 2 days. At the first visit, research staff described the study and distributed invitation letters and consent forms for students to take to their parents. Adolescents were instructed to return consent forms regardless of their decision to participate. Researchers returned to classes 5–7 days later to collect signed consent and assent forms and to oversee completion of a questionnaire packet during class that included (but was not limited to) the measures described below. Adolescents who returned consent forms, even if they chose not to participate, were entered into a lottery to win one of ten $20 gift cards. Those who participated were entered into another lottery to win 1 of 50 $20 gift cards.

Clinic Site

Adolescent medicine clinic staff approached potential participants and provided a brief study description. If adolescents expressed interest, research team members provided a detailed description of the study procedures and its risks and benefits, and then obtained written parental consent and adolescent assent. Adolescents were seated away from their parents and completed the same packet of questionnaires as used in schools. Participants were also entered into the lottery for adolescents who participated, but not the lottery for returning consent forms because they completed consent forms the same day.

Measures

Student Information Form

The study-specific Student Information Form assessed demographic information, such as gender and SES. However, because adolescents often are not fully aware of family financial status, and consistent with other adolescent ECIG studies (Jenson, 2018), a school-level variable—percentage of students receiving free/reduced price lunches (derived from the U.S. Department of Education via the Civil Rights Data Collection [U.S. Department of Education, 2015])—was used as a more objective measure of SES. Participant gender and SES were thought to belong to the *Social Environment* domain of PBT.

Youth Risk Behavior Survey: Tobacco, E-Cigarette, Alcohol, and Cannabis Use

The Youth Risk Behavior Survey (YRBS; Centers for Disease Control and Prevention [CDC], 2015) is an 89-item questionnaire assessing health risk behaviors in adolescents. This study administered only the tobacco, ECIG, alcohol, and cannabis sections from the 2015 version of the YRBS to obtain estimates of concurrent substance use, which were conceptualized as belonging to the *Behavior* domain of PBT (Jessor, 1991). Participants were asked how often then used

cigarettes, alcohol, and cannabis in the past 30 days (ranging from 0 to all 30 days). However, a large proportion of participants endorsed never using cigarettes (74.3%), alcohol (43.4%), and cannabis (87.8%). This presented issues when trying to conduct the statistical analyses, so it was decided to collapse groups. Lifetime cannabis use was measured dichotomously (yes/no). Alcohol and cigarette use were measured categorically with participants having (a) never used, (b) used but not in the past 30 days, or (c) used in the past 30 days. Questions about peer (i.e., number of five closest friends who had used an ECIG at least once) and parent (yes/no) ECIG use was added; these data were conceptualized as belonging to the *Perceived Environment* domain of PBT. Finally, participants responded to two questions asking (a) if they had tried an ECIG in their lifetime, and (b) if they had used an ECIG in the past 30 days. Responses to these two items were combined to create 3 nonoverlapping categories of ECIG use: (a) Never used an ECIG ("never users"), (b) Used an ECIG, but not in the past 30 days ("ever users"), and (c) Used an ECIG in the past 30 days ("current users"). The YRBS is revised biennially, so psychometric data are not available for the 2015 version. However, studies support the test–retest reliability (Brener et al., 2002) and convergent validity (Brener et al., 2003) of past iterations of this measure.

E-Cigarette Expectancy Scale for Adolescents

The E-Cigarette Expectancy Scale for Adolescents (EESA; Enlow et al., 2020) is a 39-item self-report survey in which adolescents rate their perceived likelihood of certain outcomes if they used an ECIG on a 10-point Likert-type scale from 0 (*completely unlikely*) to 9 (*completely likely*). Higher scores reflect more perceived costs (e.g., physical, social) or benefits (e.g., social, mood) of using an ECIG, respectively. The EESA yields three subscales (Costs, Social Benefits, and Affective Benefits) that demonstrated convergent validity with ECIG use and conceptually related variables (e.g., sensation-seeking, peer/parent ECIG use) and possessed strong internal consistency (α's = .88–.97). The EESA subscales were conceptualized as belonging to the *Personality* domain of PBT.

Brief Sensation-Seeking Scale

The Brief Sensation-Seeking Scale (BSSS; Hoyle et al., 2002) is an 8-item self-report questionnaire. Adolescents indicated how much they agree with statements such as "I like wild parties" using a 5-point Likert-type scale from 1 (*strongly disagree*) to 5 (*strongly agree*). Scores were averaged to yield an overall sensation-seeking score; higher scores indicated more sensation-seeking. The BSSS demonstrated acceptable internal consistency for the current sample (α = .77). The BSSS was thought to belong to the *Personality* domain of PBT.

Mini International Personality Item Pool

The Mini International Personality Item Pool (Donnellan et al., 2006) is a 20-item self-report questionnaire that measures five personality characteristics: (a) Extraversion, (b) Agreeableness, (c) Conscientiousness, (d) Neuroticism, and (e) Intellect/Imagination. Adolescents indicate the accuracy of statements such as "[I] am the life of the party" using a 5-point Likert-type scale from 1 (*very inaccurate*) to 5 (*very accurate*). Responses were averaged to yield five subscale scores, with higher scores indicated greater levels of the respective personality trait. Extraversion, Neuroticism, and Conscientiousness personality traits are associated with cigarette use (Munafo et al., 2007; Terracciano et al., 2008). The Extraversion (α = .81) and Conscientiousness (α = .63) subscales were used in analyses and demonstrated good and fair internal consistency, respectively. The Neuroticism subscale demonstrated low internal consistency with the current sample (α = .45); thus, it was excluded from analyses. Extraversion and conscientiousness were thought to be long to the *Personality* domain of PBT.

Statistical Analyses

Multinomial logistic regression was used to identify variables from PBT that differentiate among ECIG use status. The level of ECIG use was defined as: (a) Never users, (b) Ever users, and (c) Current users. Due to the dearth of literature differentiating between Ever versus Never and Current ECIG use, we selected Ever users as the reference group. Predictor variables mapped onto the four PBT domains (Jessor, 1991): *Social Environment* (participant gender, percent free/reduced price lunches), *Perceived Environment* (peer and parent use of ECIG), *Personality* (perceived costs and benefits of ECIG use, extraversion, conscientiousness), and *Behavior* (participants' reports of cigarette, alcohol, and cannabis use). The *Biology/Genetic* domain was omitted because the data collection approach (i.e., adolescents completing measures) did not provide confidence that adolescents could report on relevant variables (e.g., family history of substance dependence, personal intelligence) in a valid manner.

Results

Preliminary Analyses

Data Cleaning

Three participants were excluded from analyses due to concerns about their responses to questionnaires (i.e., too brief in completion time; responses outside the range of possible responses). Three additional

participants were identified as multivariate outliers and excluded. Fisher's exact tests and independent sample t-tests indicated that there were no statistically significant differences between the participants who were excluded from analyses and those who were retained with regards to gender, race/ethnicity, year in school, ever ECIG use, or age (p's $> .05$). Data were reviewed for missing values and to ensure data were missing at random. A total of 15.4% ($N = 88$) of the sample had missing data on at least one of the predictor variables; across all predictors, the proportion of participants with missing data ranged from 0.2% to 2.5%. Little's MCAR test indicated data were missing completely at random. Linear regression multiple imputation was used for independent variables with 1% or more missing data. Twenty imputations were performed based on Graham et al.'s (2007) guidelines, which resulted in data from 556 participants being included in analyses.

Descriptives

Descriptive statistics were computed for demographics and predictor and outcome variables prior to imputation (Table I). The racial/ethnic composition of the sample was generally representative of the schools and clinic from which participants were recruited; however, the sample contained slightly more female teens compared with the overall school populations (Supplementary Table S1). Review of estimates of skewness and kurtosis indicated that the distributions of variables were within acceptable limits.

Between-State Comparisons

Prior to imputation, one-way analysis of variance and Pearson's Chi-Square were used to examine differences in predictor and outcome variables as a function of participants' state of residence (OH, WV, and PA; Table I). There were statistically significant differences in percent of students receiving free/reduce price lunches ($F[2, 554] = 963.94$, $p < .001$), perceived costs of using an ECIG ($F[2, 564] = 11.10$, $p < .001$), and number of close friends who had tried an ECIG ($F[2, 561] = 10.95$, $p < .001$). Pearson Chi-Square tests indicated that fewer teens from OH were less likely to report that their parent had used an ECIG compared with teens from WV or PA ($X^2[2, N = 565] = 15.86$, $p < .001$). More adolescents from OH said they never used a cigarette when compared with adolescents from WV and PA ($X^2[2, N = 565] = 18.50$, $p < .001$). Finally, ECIG use differed by state ($X^2[4, N = 564] = 22.59$, $p < .001$). When compared with teens from WV, fewer teens from OH were ever users and current users. WhenCompared with teens from PA, more teens from OH were never users than current users. Due to these differences, state was entered as a categorical covariate with OH as the reference group.

Primary Analysis

Multiple imputation provides pooled estimates for individual parameters but not full model statistics; therefore, model statistics from all 20 imputation models are summarized. The full model demonstrated good fit ($X^2[34] = 499.81$–503.99, all p's $< .001$). Review of the classification tables revealed that the model correctly categorized 78.0–79.1% of participants. The model was better at categorizing never users (94.1–94.7% correct) relative to current users (60.6–64.6% correct) and ever users (45.3–47.9% correct); however, the rates of correct classification were better than chance (33%) for all groups.

Individual parameter estimates (Table II) were examined to identify predictors of ECIG use. With respect to *Social Environment*, neither gender nor percent of students receiving free/reduced price school lunches differentiated between never versus ever, or current versus ever, ECIG use. In the *Perceived Environment* domain, peer ECIG use was associated with greater odds of being an ever user versus never user. Peer ECIG use did not differentiate between current and ever ECIG use. Regarding the *Personality* domain, adolescents were more likely to be ever users than never users if they rated themselves as more extroverted. Adolescents who perceived fewer costs and more affective benefits of ECIG were also more likely to be ever users than never users, and current users than ever users. For the *Behavior* domain, adolescents were more likely to be ever users than never users if they endorsed current or ever cigarette or alcohol use. Current cigarette use and ever cannabis use were the only statistically significant Behavior domain risk factor for current use versus ever use.

Discussion

This study examined how variables drawn from PBT domains differentiated between never use, ever use, and current use of ECIGs. Study hypotheses were partially supported, as variables from all PBT domains except the Social Environment differentiated between never use and ever use of ECIGs. Variables from only two domains differentiated between current and ever ECIG use. Our findings suggest that there are unique and shared predictors of ever and current ECIG use, which have implications for prevention and cessation interventions.

Social Environment

Contrary to initial hypotheses, neither SES nor gender differentiated between never, ever, and current ECIG use. The null finding for gender is consistent with other literature suggesting that the gender gap in ECIG use has narrowed (Kong et al., 2017). Additionally, SES was measured at the school, rather than individual, level. Other studies reporting

Table I. *Percentages or Means and Standard Deviations of Key Study Variables*

	Full sample ($N = 567$)	OH ($N = 141$)	WV ($N = 381$)	PA ($N = 45$)
Categorical variables	% (*N*)	% (*N*)	% (*N*)	% (*N*)
Gender (female)	59.0 (334)	56.74 (80)	60.63 (231)	51.11 (23)
Race/Ethnicity				
White, Non-Hispanic	83.93 (470)	87.14 (122)	83.73 (314)	75.56 (34)
Black, Non-Hispanic	3.75 (21)	0.71 (1)	4.27 (16)	11.11 (4)
Asian, Non-Hispanic	4.29 (24)	5.71 (8)	3.73 (14)	4.44 (2)
Mulitracial, Non-Hispanic	5.18 (29)	2.84 (4)	5.6 (21)	8.89 (4)
Hispanic/Latino/a	1.96 (11)	1.43 (2)	2.13 (8)	2.22 (1)
Other	0.90 (5)	2.13 (3)	0.53 (2)	0.00 (0)
Parents ever used an ECIG (yes)	15.58 (88)	5.00 (7)[a,b]	18.95 (72)	20.00 (9)
Cigarette use				
Never used	74.5 (420)	87.9 (124)[a,b]	70.4 (266)	66.78 (30)
Used, but not in past 30 days	17.7 (100)	7.8 (11)[a]	22.0 (83)	13.3 (6)
Used in past 30 days	7.8 (44)	4.3 (6)[b]	7.7 (29)[c]	20.0 (9)
Alcohol use				
Never used	43.4 (246)	39.72 (56)	49.19 (176)	31.11 (14)
Used, but not in past 30 days	26.63 (151)	29.80 (42)	25.20 (96)	28.89 (13)
Used in past 30 days	30.00 (170)	30.50 (43)	28.60 (109)	40.00 (18)
Lifetime cannabis use (yes)	12.19 (69)	9.92 (14)	12.11 (49)	13.33 (6)
ECIG use				
Never used	61.30 (346)	75.71 (106)[a,b]	57.78 (219)	46.67 (21)
Former use	21.10 (119)	13.57 (19)	24.01 (91)	20.00 (9)
Current use	17.60 (99)	10.71 (15)[b]	18.21 (69)	33.33 (15)
Continuous variables	*M* (SD)	*M* (SD)	*M* (SD)	*M* (SD)
Percent of Students Receiving Free/ Reduced Lunch	26.66 (14.94)	4.60 (0)[a,b]	33.00 (8.63)[c]	43.56 (1.63)
Number of 5 closest friends who tried an ECIG	2.98 (1.91)	2.33 (1.78)[a,b]	3.15 (1.90)	3.38 (1.98)
Sensation seeking[d]	3.11 (0.71)	3.10 (0.71)	3.10 (0.71)	3.26 (0.68)
Costs (social, health) of ECIG use[e]	4.74 (2.60)	5.57 (2.22)[a,b]	4.53 (2.63)	3.90 (2.89)
Affective Benefits of ECIG use[e]	2.58 (1.92)	2.81 (1.70)	2.51 (1.96)	2.44 (2.18)
Social Benefits of ECIG use[e]	1.19 (1.55)	1.00 (1.13)	1.26 (1.63)	1.24 (1.97)
Extraversion[f]	3.13 (0.99)	3.26 (0.91)	3.08 (1.01)	3.13 (0.99)
Conscientiousness[f]	3.41 (0.80)	3.41 (0.73)	3.41 (0.82)	3.32 (0.88)

[a]Statistically significant difference between OH and WV.
[b]Statistically significant difference between OH and PA.
[c]Statistically significant difference between WV and PA.
[d]Higher values indicate higher self-reported sensation-seeking; scale range 1–5.
[e]Higher values indicate more perceived benefits or costs of using an e-cigarette; scale range 1–5.
[f]Higher values indicate higher self-report of personality trait; scale range 1–5.

associations between SES and ECIG use measured SES at the individual (Simon et al., 2018) or neighborhood level (Giovenco et al 2019). Therefore, individual- or neighborhood-level SES may be more specific or sensitive and thus a stronger determinant of ECIG use. Additionally, factors not assessed in this study but included in the Social Domain of PBT (neighborhood problems, social cohesion; Jessor, 1991) have demonstrated associations with ECIG use (Shih et al., 2017) and may be important areas for future investigation.

Perceived Environment

Greater ECIG use among peers was associated with greater odds of being an ever versus never ECIG user, which is consistent with findings from previous studies (e.g., Barrington-Trimis et al., 2016). However, peer ECIG use did not differentiate between current and ever ECIG use. This pattern of findings may be because adolescents who use ECIGs, regardless of frequency/quantity, are more likely to socialize with other teens who also use ECIGs. Parent ECIG use was also not related to ECIG use. The observed association between peer ECIG use and ever ECIG use among adolescents suggests that peers may exert a stronger influence over adolescents' decisions to try ECIGs than parents do, which is consistent with the broader literature on social influences on decision-making during adolescence (Ciranka & van den Bos, 2020). The association between peer ECIG use and ever use suggests that smoking cessation and prevention programs that incorporate peers, such as Peers Against Tobacco (2019), may also be effective at preventing ECIG use.

Personality

Findings from this study reinforced the importance of outcome expectancies as predictors of ECIG use

Table II. *Multinomial Logistic Regression Predicting Levels of E-cigarette Use*

	Never vs. ever ECIG use		Current vs. ever ECIG use	
	Wald (SE)	OR (95% CI)	Wald (SE)	OR (95% CI)
Covariates				
State				
PA[a]	0.00 (1.09)	0.99 (0.12–8.35)	3.52 (1.08)	7.52 (0.91-61.85)
WV[a]	0.01 (0.77)	1.06 (0.24–4.78)	0.95 (0.80)	2.17 (0.46–10.31)
Social environment				
Male gender (risk)	0.13 (0.34)	0.89 (0.46–1.72)	0.17 (0.32)	0.88 (0.46–1.65)
SES (protective)[b]	1.53 (0.02)	0.97 (0.93–1.02)	1.89 (0.02)	0.97 (0.93–1.01)
Perceived environment				
Peer E-cigarette use (risk)	38.84 (0.10)***	0.53 (0.43–0.64)	1.09 (0.11)	1.12 (0.91–1.38)
Parent E-cigarette use[c] (risk)	1.23 (0.43)	0.62 (0.26–1.45)	0.81 (0.37)	1.39 (0.68–2.85)
Personality				
Sensation seeking (risk)	3.33 (0.27)	1.67 (0.97–2.87)	1.54 (0.30)	1.45 (0.81–2.62)
General costs (social, health; protective)	12.75 (0.71)***	1.29 (1.12–1.48)	9.07 (0.08)**	0.78 (0.67–0.92)
Affective Benefits (risk)	7.68 (0.12)**	0.72 (0.57–0.91)	5.90 (0.10)*	1.28 (1.05–1.57)
Social Benefits (risk)	0.02 (0.13)	1.02 (0.79–1.31)	0.87 (0.10)	0.91 (0.76–1.10)
Extraversion (risk)	8.58 (0.20)**	0.55 (0.37–0.82)	0.67 (0.19)	0.85 (0.59–1.24)
Conscientiousness (protective)	3.42 (0.21)	1.49 (0.98–2.26)	0.09 (0.21)	0.94 (0.62–1.43)
Behavior				
Cigarette use (risk)				
Current use[c]	4.69 (0.81)*	0.17 (0.36–0.85)	4.32 (0.50)*	2.81 (1.06–7.46)
Ever use[c]	20.52 (0.43)***	0.14 (0.06–0.33)	0.20 (0.38)	1.06 (0.50–2.24)
Alcohol use (risk)				
Current use[c]	7.47 (0.40)**	0.34 (0.16–0.74)	0.16 (0.47)	1.21 (0.48–3.01)
Ever use[c]	10.38 (0.46)**	0.23 (0.09–0.56)	0.14 (0.48)	0.83 (0.33–2.14)
Cannabis—ever use (risk)[c]	2.07 (0.63)	0.40 (0.12–1.39)	9.02 (0.38)**	3.15 (1.49–6.67)

Notes. Variables are identified as risk or protective factors in superscript.
[a]OH is the reference group.
[b]Percent of students receiving free/reduced price school lunches.
[c]Never use is the reference category.
*$p < .05$,
**$p < .01$,
***$p < .001$.

(Barrington-Trimis et al., 2016; Pokhrel et al., 2018). These results build upon the extant research by indicating that individuals with more expected costs are significantly more likely to be ever ECIG users than current users (Pokhrel et al., 2014). Adolescents may believe that more regular ECIG use will lead to negative consequences, but infrequent use will not. Conversely, youth who perceive ECIG use as resulting in affective benefits may use ECIGs more frequently to achieve these benefits. Interventions that aim to prevent or reduce ECIG use would benefit from educational components that highlight the costs of using ECIGs, as well as also teaching emotion regulation skills to help adolescents cope with stressors without using ECIGs.

Neither sensation-seeking nor social benefits were associated with ECIG use. In a previous regression model, in which state was not entered as a covariate, higher sensation-seeking was associated with greater odds of ever ECIG use. However, this effect became non-significant after controlling for state and the effect for sensation-seeking was relatively small. Therefore, it may be that sensation-seeking was not a strong enough predictor of ever ECIG use after accounting for other predictors. The null finding regarding social benefits is consistent with studies that included ECIG expectancies in multivariate analyses (Barker et al., 2019). It may be that the perceived social benefits of ECIG use are related to other variables, such as peer ECIG use. For instance, adolescents may perceive more social benefits if their peers use ECIGs but fewer benefits if their peers do not. These null findings stress the importance of evaluating multilevel predictors of adolescent ECIG use within the same study, as well as the effects of nested data.

A novel finding in this study was also that higher levels of extraversion were associated with greater odds of being an ever ECIG user, relative to a never user. This reinforces the importance of personality in relation to adolescent use of tobacco products (Harakeh et al., 2006). Contrary to our original hypotheses, conscientiousness was not associated with ECIG use. Teens that are more conscientious are thought to be less likely to use substances because they

are more likely to follow rules and social norms (Jackson et al., 2010). Therefore, it may be that conscientiousness was not related to ECIG use because it is considered to be a less deviant form of substance use.

Behavior

Substance use behaviors were associated with ECIG use (similar to Barrington-Trimis et al., 2016; Wills et al., 2021). It is notable that the patterns of associations differed between never versus ever and current versus ever ECIG use. Adolescents who ever or currently used alcohol or cigarettes had greater odds of reporting that they had ever used an ECIG. However, only current cigarette use was associated with greater odds of being a current ECIG user. Interestingly, adolescents' cannabis use increased their risk for being a current ECIG user compared with an ever ECIG user, but it did not distinguish adolescents who were ever ECIG users from those who have never used ECIGs. This finding is consistent with other research that demonstrates associations between ECIG and cannabis use within the past 30 days (Evans-Polce et al., 2020) or past 6 months (Park et al., 2020). This comorbidity may be partially due to heritable influences, which is also thought to explain overlaps in tobacco and cannabis use (Verweij et al., 2010), common route of administration via inhalation (Agrawal et al., 2012), or the fact that early cannabis use may also introduce adolescents to a peer group with more favorable attitudes towards smoking, thereby increasing risk for current ECIG use (Agrawal et al., 2012). Nevertheless, additional research is needed.

Limitations and Future Directions

Although this study provides valuable insight into the factors that differentiate current ECIG users and ever ECIG users using a PBT framework, results must be considered in light of some limitations. The sample was predominantly White, generally academically successful, and recruited from one region of the United States, which may limit generalizability. This study utilized a cross-sectional, correlational design, which limits the ability to make causal or directional inferences and precluded the examination of direct and indirect effects of different variables. Future research should utilize longitudinal data to examine the mechanisms through which these associations occur. For instance, adolescents' personality may influence ECIG use through social influences. All measures used adolescent-reported data, which enhances the influence of shared method variance and social desirability bias. It was also not possible to evaluate the full range of responses to ECIG and substance use questions due to small cell sizes, which limits our understanding of how variables in the PBT model predict frequency of ECIG use. Finally, adolescents may have under- or over-reported substance use. However, efforts were made to guard against social desirability (e.g., ensuring confidentiality) and rates of ECIG use in this study were comparable to other studies (Kann et al., 2018). Future research should recruit nationally representative samples, use longitudinal designs, and employ a multi-informant approach.

Conclusion

This study describes the important role of a comprehensive set of PBT variables as risk factors for ever ECIG use. The findings also highlight the unique role of the perceived costs and affective benefits of ECIG use, as well as current cigarette and ever cannabis use as risk factors for current ECIG use compared with ever ECIG use among adolescents. Additional research should examine these associations in more diverse samples and using longitudinal designs. Current findings can inform future research aimed at improving screening of ECIG use, such as identifying expectancies or other substance use behaviors that are predictive of initiating or escalating ECIG use. Ascertaining these unique predictors will also help distill specific factors that should be incorporated into programs to prevent ECIG initiation from those that should be incorporated into cessation interventions for current ECIG users.

Supplementary Data

Supplementary data can be found at: https://academic.oup.com/jpepsy.

Acknowledgments

We would like to thank the students who participated in this study, the school administrators and teachers for their support in conducting this study, and Nicole Pellegrino (undergraduate research assistant) for all of her help with this study.

Funding

This work was supported by West Virginia University (WVU; Eberly College of Arts and Sciences Doctoral Research Grant and Department of Psychology Doctoral Research Fund to P.T.E.); the US Centers for Disease Control and Prevention (CDC; U48DP006391 to M.D.B); and the National Institute of General Medical Sciences (NIGMS; T32 GM081741 to D.N.W.). The findings and conclusions in this publication are those of the authors and do not necessarily represent the official position of WVU, the CDC or the NIGMS.

Conflicts of interest: None declared.

References

Alexander, A. C., Obong'o, C. O., Chavan, P., Vander Weg, M. W., & Ward, K. D. (2018). Applying the Problem Behavior Theory to adolescent drug use among a cross-sectional sample of boys participating in a community-based youth organization. *Substance Use & Misuse*, *53*(4), 610–621.

Agrawal, A., Budney, A. J., & Lynskey, M. T. (2012). The co-occurring use and misuse of cannabis and tobacco: A review. *Addiction (Abingdon, England)*, *107*(7), 1221–1233. https://doi.org/10.1111/j.1360-0443.2012.03837.x

Azagba, S., Manzione, L., Shan, L., & King, J. (2020). Trends in smoking behaviors among US adolescent cigarette smokers. *Pediatrics*, *145*(3), e20193047. https://doi.org/10.1542/peds.2019-3047

Barker, J. O., Kelley, D. E., Noar, S. M., Reboussin, B. A., Cornacchione Ross, J., & Sutfin, E.L. (2019). E-cigarette outcome expectancies among nationally representative samples of adolescents and young adults. *Substance Use & Misuse*, *54*(12), 1970–1979. https://doi.org/10.1080/10826084.2019.1624773

Barrington-Trimis, J. L., Urman, R., Leventhal, A. M., Gauderman, W. J., Cruz, T. B., Gilreath, T. D., Howland, S., Unger, J. B., Berhane, K., Samet, J. M., & McConnell, R. (2016). E-cigarettes, cigarettes, and the prevalence of adolescent tobacco use. *Pediatrics*, *138*(2), e20153983. https://doi.org/10.1542/peds.2015-3983

Bold, K. W., Kong, G., Camenga, D. R., Simon, P., Cavallo, D. A., Morean, M. E., & Krishnan-Sarin, S. (2018). Trajectories of e-cigarette and conventional cigarette use among youth. *Pediatrics*, *141*(1), e20171832. https://doi.org/10.1542/peds.2017-1832

Brener, N. D., Billy, J. O. G., & Grady, W. R. (2003). Assessment of factors affecting the validity of self-reported health-risk behavior among adolescents: Evidence from the scientific literature. *The Journal of Adolescent Health*, *33*(6), 436–457. https://doi.org/10.1016/S1054-139X(03)00052-1

Brener, N. D., Kann, L., McManus, T., Kinchen, S. A., Sundberg, E. C., & Ross, J. G. (2002). Reliability of the 1999 Youth Risk Behavior Survey Questionnaire. *The Journal of Adolescent Health*, *31*(4), 336–342. https://doi.org/10.1016/S1054-139X(02)00339-7

Burnley, A., Bold, K. W., Kong, G., Wu, R., & Krishnan-Sarin, S. (2021). E-cigarette use perceptions that differentiate e-cigarette susceptibility and use among high school students. *The American Journal of Drug and Alcohol Abuse*, *47*(2), 238–239. https://doi.org/10.1080/00952990.2020.1826501

Case, K. R., Loukas, A., Harrell, M. B., Wilkinson, A. V., Springer, A. E., Pérez, A., Creamer, M. R., & Perry, C. L. (2017). The association between sensation seeking and e-cigarette use in Texas young adults: A cross-sectional study. *Journal of American College Health*, *65*(4), 277–285.

Centers for Diesease Control and Prevention (CDC). (2015). Youth Risk Behavior Survey. https://www.cdc.gov/healthyyouth/data/yrbs/index.htm. Retrieved 13 March 2019.

Chassin, L., Presson, C. C., Pitts, S. C., & Sherman, S. J. (2000). The natural history of cigarette smoking from adolescence to adulthood in a midwestern community sample: Multiple trajectories and their psychosocial correlates. *Health Psychology*, *19*(3), 223–231.

Ciranka, S., & van den Bos, W. (2020). Social influence in adolescent decision-making: a formal framwork. *Frontiers in Psychology*, *11*, 598347. https://doi.org/10.3389/fpsyg.2019.01915

Costello, D. M., Dierker, L. C., Jones, B. L., & Rose, J. S. (2008). Trajectories of smoking from adolescence to early adulthood and their psychosocial risk factors. *Health Psychology*, *27*(6), 811–818. https://doi.org/10.1037/0278-6133.27.6.811

Donovan, J. E., & Molina, B. S. G. (2014). Antecedent predictors of children's initiation of sipping/tasting alcohol. *Alcoholism, Clinical and Experimental Research*, *38*(9), 2488–2495. https://doi.org/10.1111/acer.12517

Donnellan, M. B., Oswald, F. L., Baird, B. M., & Lucas, R. E. (2006). The MINI-IPIP scales: Tiny-yet-effective measures of the big five factors of personality. *Psychological Assessment*, *18*(2), 192–203. https://doi.org/10.1037/1040-3590.18.2.192

East, K., Hitchman, S. C., Bakolis, I., Williams, S., Cheeseman, H., Arnott, D., & Mcneill, A. (2018). The association between smoking and electronic cigarette use in a cohort of young people. *Journal of Adolescent Health*, *62*, 539–547. https://doi.org/10.1016/j.jadohealt.2017.11.301

Enlow, P. T., Felicione, N., Williford, D. N., Durkin, K., Blank, M. D., & Duncan, C. L. (2020). Validation of the electronic cigarette expectancy scale for adolescents (EESA) [Manuscript Submitted for Publication].

Evans-Polce, R. J., Veliz, P. T., Boyd, C. J., & McCabe, S. E. (2020). E-cigarette and cigarette use among U.S. adolescents: Longitudinal associations with marijuana use and perceptions. *American Journal of Preventive Medicine*, *58*(6), 854–857. https://doi.org/10.1016/j.amepre.2020.01.013

Giovenco, D. P., Spillane, T. E., & Merizier, J. M. (2019). Neighborhood differences in alternative tobacco product availability and advertising in New York City: Implications for health disparities. *Nicotine & Tobacco Research*, *21*(7), 896–902. https://doi.org/10.1093/ntr/nty244

Goniewicz, M. L., Smith, D. M., Edwards, K. C., Blount, B. C., Caldwell, K. L., Feng, J., Wang, L., Christensen, C., Ambrose, B., Borek, N., van Bemmel, D., Konkel, K., Erives, G., Stanton, C. A., Lambert, E., Kimmel, H. L., Hatsukami, D., Hecht, S. S., Niaura, R. S., … Hyland, A. J. (2018). Comparison of nicotine and toxicant exposure in users of electronic cigarettes and combustible cigarettes. *JAMA Network Open*, *1*(8), e185937. https://doi.org/10.1001/jamanetworkopen.2018.5937

Graham, J. W., Olchowski, A. E., & Gilreath, T. D. (2007). How many imputations are really needed? Some practical clarifications of multiple imputation theory. *Prevention Science*, *8*(3), 206–213. https://doi.org/10.1007/s11121-007-0070-9

Harakeh, Z., Scholte, R. H. J., de Vries, H., & Engels, R. C. M. E. (2006). Association between personality and adolescent smoking. *Addictive Behaviors*, *31*(2), 232–245. https://doi.org/10.1016/j.addbeh.2005.05.003

Hoyle, R. H., Stephenson, M. T., Palmgreen, P., Pugzles, E., & Donohew, R. L. (2002). Reliability and validity of a

brief measure of sensation seeking. *Personality and Individual Differences*, *32*(3), 401–414. https://doi.org/10.1016/S0191-8869(01)00032-0

Jackson, J. J., Wood, D., Bogg, T., Walton, K. E., Harms, P. D., & Roberts, B. W. (2010). What do conscientious people do? Development and validation of the Behavioral Indicators of Conscientiousness (BIC). *Journal of Research in Personality*, *44*(4), 501–511. https://doi.org/10.1016/j.jrp.2010.06.005

Jenson, T. E. (2018). Psychosocial and behavioral risk profiles of cigarette smokers and e-cigarette users among adolescents in Minnesota: The 2016 Minnesota student survey. *Preventing Chronic Disease*, *15*, E118–E10. https://doi.org/10.5888/pcd15.180222

Jessor, R. (1991). Risk behavior in adolescence: A psychosocial framework for understanding and action. *Journal of Adolescent Health*, *12*(8), 597–605. 10.1016/1054-139X(91)90007-K

Kann, L., McManus, T., Harris, W. A., Shanklin, S. L., Flint, K. H., Queen, B., Lowry, R., Chyen, D., Whittle, L., Thornton, J., Lim, C., Bradford, D., Yamakawa, Y., Leon, M., Brener, N., & Ethier, K. A. (2018). Youth risk behavior surveillance - United States, 2017. *Morbidity and Mortality Weekly Report*, *67*(8), 1–114. https://doi.org/10.15585/mmwr.ss6708a1

Kinnunen, J. M., Ollila, H., Minkkinen, J., Lindfors, P. L., & Rimpelä, A. H. (2018). A longitudinal study of predictors for adolescent electronic cigarette experimentation and comparison with conventional smoking. *International Journal of Environmental Research and Public Health*, *15*(2), 1–16. https://doi.org/10.3390/ijerph15020305

Kong, G., Kuguru, K. E., & Krishnan-Sarin, S. (2017). Gender differences in U.S. adolescent e cigarette use. *Current Addiction Reports*, *4*(4), 422–430. https://doi.org/10.1007/s40429-017-0176-5

Lanza, S. T., & Vasilenko, S. A. (2015). New methods shed light on age of onset as a risk factor for nicotine dependence. *Addictive Behaviors*, *50*, 161–164. https://doi.org/10.1016/j.addbeh.2015.06.024

Margolis, K. A., Thakur, S. K., Zarndt, A. N., Kemp, C. B., & Glover-Kudon, R. (2021). E -cigarette susceptibility among US middle and high school students: National Youth Tobacco Survey Data Trend Analysis, 2014–2018. *Preventive Medicine*, *143*, 106347.https://doi.org/10.1016/j.ypmed.2020.106347

Mehra, V. M., Keethakumar, A., Bohr, Y. M., Abdullah, P., & Tamim, H. (2019). The association between alcohol, marijuana, illegal drug use and current use of e-cigarette among youth and young adults in Canada: Results from Canadian Tobacco, Alcohol, and Drugs Survey 2017. *BMC Public Health*, *19*(1), 1208–1210. https://doi.org/10.1186/s12889-019-7546-y

Munafo, M. R., Zetteler, J. I., & Clark, T. G. (2007). Personality and smoking status: A meta analysis. *Nicotine & Tobacco Research*, *9*(3), 405–413. https://doi.org/10.1080/14622200701188851

Nicksic, N. E., & Barnes, A. J. (2019). Is susceptibility to E-cigarettes among youth associated with tobacco and other substance use behaviors one year later? Results from the PATH study. *Preventive Medicine*, *121*, 109–114. https://doi.org/10.1016/j.ypmed.2019.02.006

Park, E., Livingston, J. A., Wang, W., Kwon, M., Eiden, R. D., & Chang, Y. P. (2020). Adolescent E-cigarette use trajectories and subsequent alcohol and marijuana use. *Addictive Behaviors*, *103*, 106213. https://doi.org/10.1016/j.addbeh.2019.106213

Peers Against Tobacco. (2019). https://www.peersagainsttobacco.org/.

Pokhrel, P., Lam, T., Pagano, I., Kawamoto, C. T., & Herzog, T. A. (2018). Young adult ecigarette use outcome expectancies: validity of a revised scale and a short scale. *Addictive Behaviors*, *78*, 193–199. doi: 10.1016/j.addbeh.2017.11.019

Pokhrel, P., Little, M. A., Fagan, P., Muranaka, N., & Herzog, T. A. (2014). Electronic cigarette use outcome expectancies among college students. *Addictive Behaviors*, *39*(6), 1062–1065. doi: 10.1016/j.addbeh.2014.02.014

Racz, S. J., McMahon, R. J., & Luthar, S. S. (2011). Risky behavior in affluent youth: examining the co-occurrence and consequences of multiple problem behaviors. *Journal of Child and Family Studies*, *20*(1), 120–128. https://doi.org/10.1007/s10826-010-9385-4

Rubinstein, M. L., Delucchi, K., Benowitz, N. L., & Ramo, D. E. (2018). Adolescent exposure to toxic volatile organic chemicals from e-cigarettes. *Pediatrics*, *141*(4), e20173557.https://doi.org/10.1542/peds.2017-3557

Sawdey, M. D., Day, H. R., Coleman, B., Gardner, L. D., Johnson, S. E., Limpert, J., Hammad, H. T., Goniewicz, M. L., Abrams, D. B., Stanton, C. A., Pearson, J. L., Kaufman, A. R., Kimmel, H. L., Delnevo, C. D., Compton, W. M., Bansal-Travers, M., Niaura, R. S., Hyland, A., & Ambrose, B. K. (2019). Associations of risk factors of e-cigarette and cigarette use and susceptibility to use among baseline PATH study youth participants (2013– 2014). *Addictive Behaviors*, *91*, 51–60. https://doi.org/10.1016/j.addbeh.2018.11.027

Shih, R. A., Parast, L., Pedersen, E. R., Troxel, W. M., Tucker, J. S., Miles, J., Kraus, L., & D'Amico, E. J. (2017). Individual, peer, and family factor modification of neighborhood- level effects on adolescent alcohol, cigarette, e-cigarette, and marijuana use. *Drug and Alcohol Dependence*, *180*, 76–85. https://doi.org/10.1016/j.drugalcdep.2017.07.014

Simon, P., Camenga, D. R., Kong, G., Connell, C. M., Morean, M. E., Cavallo, D. A., & Krishnan-Sarin, S. (2017). Youth e-cigarette, blunt, and other tobacco use profiles: Does SES matter? *Tobacco Regulatory Science*, *3*(1), 115–127. https://doi.org/10.18001/TRS.3.1.12

Simon, P., Camenga, D., Morean, M., Kong, G., Bold, K. W., Cavallo, D. A., & Krishnan-Sarin, S. (2018). Socioeconomic status (SES) and adolescent e-cigarette use: The mediating role of e-cigarette advertisement exposure. *Preventive Medicine*, *112*, 193–198. https://doi.org/10.1016/j.ypmed.2018.04.019

Skov-Ettrup, L. S., Ringgaard, L. W., Dalum, P., Flensborg-Madsen, T., Thygesen, L. C., & Tolstrup, J. S. (2014). Comparing tailored and untailored text messages for smoking cessation: A randomized controlled trial among adolescent and young adult smokers. *Health Education Research*, *29*(2), 195–205. https://doi.org/10.1093/her/cyt112

Terracciano, A., Löckenhoff, C. E., Crum, R. M., Bienvenu, J., & Costa Jr, P. T. (2008). Five factor model personality

profiles of drug users. *BMC Psychiatry*, *10*, 1–10. https://doi.org/10.1186 /1471-244X-8-22

U.S. Department of Education. (2015). Civil Rights Data Collection. https://ocrdata.ed.gov/. Retrieved 17 January 2019.

Verweij, K. J. H., Zietsch, B. P., Lynskey, M. T., Medland, S. E., Neale, M. C., Martin, N. G., Boomsma, D. I., & Vink, J. M. (2010). Genetic and environmental influences on cannabis use initiation and problematic use: A meta-analysis of twin studies. *Addiction (Abingdon, England)*, *105*(3), 417–430. https://doi.org/10.1111/j.1360-0443.2009.02831.x

Villanti, A., Boulay, M., & Juon, H. S. (2011). Peer, parent and media influences on adolescent smoking by developmental stage. *Addictive Behaviors*, *36*(1-2), 133–136. https://doi.org/10.1016/j.addbeh.2010.08.018

Vogel, E. A., Prochaska, J. J., Ramo, D. E., Andres, J., & Rubinstein, M. L. (2019). Adolescents' E-cigarette use: increases in frequency, dependence, and nicotine exposure over 12 months. *The Journal of Adolescent Health*, *64*(6), 770–775. https://doi.org/10.1016/j.jadohealth.2019.02.019

Vogel, E. A., Ramo, D. E., & Rubinstein, M. L., (2018). Prevalence and correlates of adolescents' e-cigarette use frequency and dependence. *Drug and Alcohol Dependence*, *1881*. 109–112. https://doi.org/10.1016/j.drugalccdep.2018.03.051

Walker, M. W., Navarro, M. A., Pepper, J. K., Eggers, M. E., Nonnemaker, J. M., Kim, A. E., Homsi, G., Horn, E., & Baum, L. (2020). An investigation of definitions of experimental vaping among youth. *Tobacco Regulatory Science*, *6*(4), 289–301.

Wills, T. A., Knight, R., Sargent, J. D., Gibbons, F. X., Pagano, I., & Williams, R. J. (2021). Longitudinal study of e-cigarette use and onset of cigarette smoking among high school students in Hawaii. *Journal of the American College of Nutrition*, *26*, 1–39. https://doi.org/10.1136/tobaccocontrol-2015 -052705